XXX.—*On Preserving the Balance between the Animal and Vegetable Organisms in Sea Water.* By Robert Warington.*

In the published notices of my experiments of 1849, to maintain the balance between the animal and vegetable organisms in a confined and limited portion of water, the fact was demonstrated, that, in consequence of the natural decay of the vegetation, its subsequent decomposition and the mucus-growth to which it gave rise, this balance could only be sustained for a very short period, but, if another member were introduced, which would feed upon the decaying vegetation and thus prevent the accumulation of these destructive products—a function most admirably performed by the various species of water-snail—such balance was capable of being continuously maintained without the slightest difficulty; and I may add, that the experimental proof of this has now been carried on, in a small tank in the heart of London, for the last four years and a half, without any change or disturbance of the water; the loss which takes place by evaporation being made up with rain or distilled water, so as to avoid any great increase of the mineral ingredients originally present. It follows then, as a natural deduction, from the successful demonstration of these premises, that the same balance should be capable of being established, under analogous circumstances, in sea water. And in a paper published in January 1852†, I stated that I was, at that time, "attempting the same kind of arrangement with a confined portion of sea water, employing some of the green sea-weeds for the vegetable member of the circle, and the common periwinkle as the representative of the water-snail."

The sea water with which the experiments I am about to detail were conducted, was obtained through the medium of one of the oyster-boats at the Billingsgate fish-market, and was taken from the middle of the English Channel.

My first object was to ascertain the kind of sea-weed best fitted, under ordinary circumstances, for keeping the water clear and sweet, and in a sufficiently oxygenated state to sustain animal life. And here opinions were at variance, for one naturalist friend whom I consulted, advised me to employ the Rhodosperms; another stated that it was impossible to make the red weeds answer the purpose, as he had tried them, and strongly recommended the olive or brown-coloured Algæ; while, again, others thought that I should be more successful with those which had

* Communicated by the Author, having been read at the Hull Meeting of the British Association.

† Gardeners' Botanical Magazine and Garden Companion, Jan. 1852.

in theory first suggested themselves to my own mind, namely the Chlorosperms. After making numerous unsuccessful experiments with both the brown and the red varieties of Algæ, I was fully convinced that, under ordinary circumstances, the green weeds were the best adapted for the purpose.

This point having been practically ascertained, and some good pieces of the *Enteromorpha* and *Ulva latissima* in a healthy state, attached to nodules of flint or chalk, having been procured from the shore near Broadstairs, several living animal subjects were introduced together with the periwinkle. Everything progressed satisfactorily, and these all continued in a healthy and lively condition.

My first trials were conducted in one of the small tanks which had been used for fresh water; but as it was necessary, during the unsuccessful experiments with the brown and red sea-weeds, to agitate and aërate the water, which had been rendered foul from the quantity of mucus or gelatinous matter generated during the decay of their fronds, until the whole had become oxidized, and the water rendered clear and fitted for another experiment, it was, therefore, for greater convenience, removed into a shallow earthen pan and covered with a large glass shade to protect the surface of the water, as much as possible, from the dust and soot of the London atmosphere, and at the same time impede the evaporation. In this vessel then I had succeeded perfectly in keeping a large number of beautiful living specimens in a healthy condition up to the close of 1852. I therefore gave instructions for the making of a small tank as a more permanent reservoir, and one more adapted for carrying on my observations and investigations on the œconomy and habits of the inhabitants.

From the experience I had obtained in my experiments with the freshwater tank, I was induced to modify slightly the construction of this vessel; thus, at the back, or part towards the light, the framing was filled with slate in the same way as the ends and bottom; for I had found that the glass, originally employed, very soon became covered with a confervoid growth which had an unpleasing appearance to the eye, and in consequence of which I had been obliged to paint the glass on the exterior to prevent this growth from increasing to too great an extent. It was also an unnatural mode of illumination, as all the light should pass through the surface of the water. The front towards the room and the observer was constructed of plate-glass, the whole being set in a stout framework of zinc, and cemented with what is known under the name of Scott's cement, and which I have found to answer for the purpose most admirably. Within this tank were arranged several large pieces of rock-work, thrown into an arched form, and other fragments

were cemented in places against the slate at the back and ends, and at parts along the water-line, so that the creatures could hide themselves at pleasure; a short beach of pebbles was also constructed in order that shallow water could be resorted to if desired. The whole tank was covered with a light glass shade to keep out the dust and retard evaporation.

With the sea water obtained in January 1852, I have been working without cessation up to the present time, agitating and aërating when it became foul during the unsuccessful experiments on the sea-weeds, but since then it has been rarely ever disturbed; the loss which takes place from evaporation being made up, as before stated, with rain or distilled water.

For a considerable period, after commencing these experiments, I was much troubled to obtain living subjects in a healthy condition, but having alluded to this, and the success of my investigations, in a short notice appended to a paper published in the 'Annals of Natural History' for October 1852, my friend Mr. P. H. Gosse, who was then sojourning at Ilfracombe for his health, offered in the kindest manner possible to supply me with materials, and from that period he has always most heartily responded to my wants. It must not be imagined for a moment that the beautiful creatures I have thus received have been all preserved alive or always quite healthy. In experimental investigations this would be unreasonable to expect, as the very fact of experimenting implies a disturbance of the then state of things. Besides which, from want of a sufficient knowledge of natural history, from want of forethought and experience and other causes, I have lost many very fine specimens; and as the detail of these losses may prevent the occurrence of the like annoyances to others, I shall venture to occupy your time for a short period with their history.

My greatest loss arose from too great an anxiety to transfer the collection I had preserved in a healthy condition to the end of December 1852 into the new tank. As soon as it arrived from the maker's I lost no time in introducing my numerous family to their new abode, and dearly I paid for my precipitancy, for on the next morning I found many of my most beautiful specimens dead; thus I lost two fine Holothurias (*H. Pentactes*), a small freckled Goby (*Gobius minutus*), a beautiful little Pipe-fish (*Syngnathus lumbriciformis*), and several others, and on opening the door of the case the cause of this mortality was at once evident,—an iridescent film of oily matter was floating on the surface of the water, arising from the paint with which the angular joints and edges of the small tank had been coloured not having become sufficiently hardened.

Another source of loss arises from the several creatures attack-

ing and devouring each other, and it therefore becomes a point of great importance—and highly necessary to be carefully observed, where their preservation is an object—to ascertain what varieties may be safely associated in the same tank; as, for instance, I have found that the Shrimps and Prawns attack, and very soon devour, all the larger varieties of Corallines and Polyps, Sabellæ, Serpulæ, Rock-borers, Cirrhipeds, some of the Annelids, many Bivalve and Univalve Mollusks that are unprotected by an operculum, or have no power of closing their valves. The instances which have come under my own immediate observation have been the destruction of the *Pholas dactylus*, *Saxicava rugosa*, *Cypræa Europæa*, and several specimens of Sabellæ, Serpulæ, *Coryne sessilis* and many others.

The common Crab (*Cancer Mænas*) is likewise a most destructive agent; and the tribe of rock-fish, the Blennies, Gobies, &c. are also most voracious, devouring all the varieties of Cirrhipeds, Corallines, Polyps, Annelids, &c.; they will also attack the shrimps and prawns, and even seize upon the horns of the periwinkle, which they bite. If the mollusks do not keep a very firm hold of the rock or tank sides, they are rapidly turned over by these fish on their backs and lie helplessly exposed to their attacks*. It is doubtless their seeking food of this kind which causes these little fish to be so generally found in the shallow rock-pools of the coast. In consequence of these ravenous propensities I have been obliged to establish several small tanks and imitation rock-pools, so as to separate these various depredators from each other: thus in one I have varieties of *Actinia*, Shrimps, Nudibranchs, Holothurias, and some Annelids; in a second the rock-fish, as the Blennies, Gobies, Cottus, with Crabs and *Actiniæ*; in a third Corallines, Annelids, Polyps, Rock-borers, Sabellæ, Serpulæ, Holothurias, and *Actiniæ*.

Another curious instance of loss I may detail which has quite recently occurred, and which may prove interesting; it was in a small rock-pool containing Blennies, Gobies, Crabs, &c. I had procured two live oysters for the purpose of feeding my numerous small fry in these vivaria, and one of these having proved ample for the purpose of one meal, the other was placed on the

* Since the reading of this paper at Hull I have received a Blenny of larger size, being about 3½ inches in length, and although it has become so tame that it will allow itself to be touched by the hand and takes its food from the fingers, yet its destructive propensities are so great, that it very soon killed four small Crabs; and to save three others, of rather a larger size, I have been obliged to remove the Blenny to a rock-pool in association with his own species and a few *Actiniæ*. The only refuge the poor Crabs had was to bury themselves in the sand, and whenever they attempted to move out of their refuge they were immediately pounced upon and only escaped by burrowing rapidly again.

sandy bottom; on the second day after this the oyster was observed to have opened the valves of his shell to a great extent, which were afterwards seen closed, but a small *Gobius niger*, inhabiting the pool, could nowhere be seen. The day after this the oyster was opened for the general feeding, when, lo! within the shell was found the unfortunate *Gobius*, quite dead. Whether this little gentleman had been attracted within the trap by curiosity or the ciliary motion of the oyster, it is impossible with certainty to say; but that he must have seized on some sensitive part of the oyster is more than probable, so as to have caused such a rapid closing of the valves of the shell as could entrap so active a burglar.

Another important point is the gravity of the sea water; this should be very carefully regulated, for it must be borne in mind that many of the marine creatures are supplied by a permeation of water through their tissues or over their delicate and beautiful organs. The specific gravity should not rise above 1026 at 60° Fahr., and a small hydrometer should be at short periods introduced to ascertain that this point is not exceeded, particularly during the hot months of summer. The reduction to this gravity can be readily effected by the addition of rain or distilled water. Many of the creatures will of themselves afford indications of this increase of density; some of the *Actiniæ* will remain closed and become coated with a white slimy covering within which they remain for a length of time, and if the specific gravity of the water be lowered this is very soon ruptured by their expansion, thrown off, and the tentacula become soon extended.

All putrescent matter or excess of food or rejecta of the *Actiniæ* should be carefully removed from the water, as the noxious gaseous compounds generated by the decay of such matters appear to diffuse themselves rapidly through the water, act as a virulent poison, and speedily destroy the vitality of the occupants. Thus many beautiful subjects were lost in a few hours from the introduction, into a small glass jar, of a large Pecten shell, encrusted with corallines, which had become loaded with putrescent matter by partial submersion in a foul muddy bottom.

Great care should also be taken in moving the *Actiniæ* that the foot or sucking disc with which it attaches itself to the rocks, stones, or mud, be not injured, as, when this occurs, they rarely survive, but roll about without attaching themselves, and gradually waste away and die.

With these exceptions then, everything has gone on very satisfactorily, care being always taken not to overload the water with too large a proportion of animal life for the vegetation to balance, as, whenever this has been inadvertently attempted, the

water has soon become foul, and the whole contents of the tank, both animal and vegetable, have rapidly suffered, and it has required some time before the water could be restored to its former healthy condition.

In one of the numbers of the 'Zoologist' of last year, I stated that besides the *Ulvæ*, *Enteromorphæ* and *Cladophoræ*, I had found the *Zostera marina* a very useful plant for oxygenating the sea water; but this observation has reference only to the case of a tank supplied with a ground where its roots will find a sufficiency of food for its growth, as in a clear shingle or sand it soon decays; and it should be associated with such animals as delight in a ground of this nature, as many of the Annelids, Crabs, burrowing Shrimps, &c. There are several interesting observations which have been made from time to time connected with this subject, which I hope to lay before the natural-history world as soon as I can find leisure time for the purpose.

Apothecaries' Hall, Sept. 10, 1853.

XXXI.—*On the Cornbrash of the neighbourhood of Cirencester.* By James Buckman, F.L.S., F.G.S., Professor of Geology Royal Agricultural College*.

The Cornbrash as it occurs in the neighbourhood of Cirencester, though for the most part a very thin member of the Oolitic series of rocks, yet presents us with many points for consideration of great interest.

In the counties of Gloucester and Wilts it is always found to rest upon a thick bed of Forest marble clay, a section at Kemble, four miles from Cirencester, being as follows in descending order:—

	ft.	in.
1. *Cornbrash*, an oolitic stone, with rough uneven fracture and full of shells	8	0
2. Blue clay without shells	17	0
3. Siliceous limestone ... *Forest marble*	6	0
4. *Bradford clay*, very fossiliferous	7	0
5. Great Oolite		

The bed No. 1, which it is our object to describe in the following remarks, though of so slight thickness, is found to be the substratum of large tracts of land, especially in the neighbourhood of Cirencester, Fairford, Cricklade, and Malmsbury; in each case presenting great and beneficial peculiarities of soil, not only when compared with that upon its surrounding forest marble, but also in comparison with other oolitic brashes; indeed, its name "Cornbrash" would appear to have been given to it from the fact that its soil affords a brash or stony soil

* Read to the Cotteswold Naturalists' Club, Sept. 20, 1853.